Design of Rhodium-Platinum Furnace Elements

LONG LIFE AT HIGH TEMPERATURES

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The design of high temperature furnaces incorporating internally wound 20 per cent rhodium-platinum heating elements has been developed and improved over many years at the Building Research Station. The type of construction described here permits a higher furnace temperature to be obtained for a given winding temperature than is possible with other constructions, and yet enables good working lives to be achieved.

High temperature furnaces are needed in the course of the activities of the Building Research Station for the preparation of experimental cements and synthetic slags and glasses, as well as for research on chemical compounds and phases that occur in building materials during the heat treatment associated with their manufacture. In addition, they are used for the study of high temperature phase equilibria in systems relevant to the constitution of cements, slags and ceramics. The furnaces described are the result of continual development over a long period.

In the construction of a muffle type furnace a mould and former are used. The former consists of three wedge-shaped pieces of aluminium, the centre piece of which is keyed and tapered to facilitate withdrawal of the former after the element has been wound. Two detachable posts on the former allow the wire to be anchored. A mould and former for a D-shaped element are show in Fig. 1. The paper covering the former is marked ready for winding. Similar moulds are in use for the construction of tubular elements of 2.5 and 5.0 cm internal diameter.

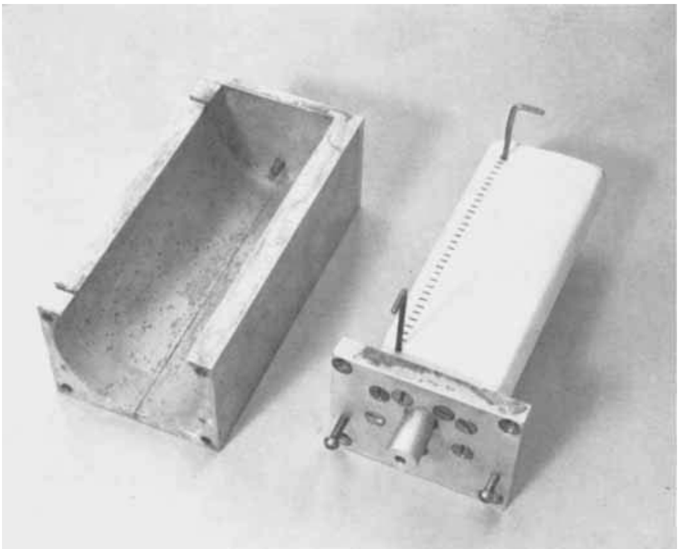

Fig. 1 The mould and former for a D-shaped element of internal dimensions 12.5 × 5 × 3.5 cm. The paper covering the former is marked ready for winding the 20 per cent rhodium-platinum wire.

The parts of the former are greased, assembled and wrapped with two layers of filter paper, and the winding posts are inserted. The filter paper is marked to guide the winding of the 0.8 mm diameter 20 per cent rhodium-platinum wire. The wire, at about 25 cm from its free end, is attached to one winding post on the former and the element is carefully wound, an even tension being maintained. On completion of winding the wire is attached to the other winding post and, allowing for 25 cm for the lead, the wire is cut. The former is then fixed in the mould case and the space between the former and the case filled with the alumina refractory, the grading and water ratio of which are given in the table.

Composition of Alumina Refractory for One Element

Material	Quantity
−10+20 mesh fused alumina	167 g
−20+60 mesh fused alumina	111 g
−60+120 mesh fused alumina	56 g
Morgans Alumina Cement 961	167 g
Water	50–60 ml

This mix has low plasticity and must be compacted on a vibrating table. When the mould has been filled and compacted it is dried in an oven at 80°C for a day. The element is then strong enough to be removed from the mould and the centre of the former is gently drawn out of the element. The remainder of the former and mould can then easily be removed.

The element is fired in a box of alumina powder by passing an a.c. current through the winding. It is raised to 1400°C in about three hours, and then cooled. A thin slip of alumina cement is run around the inside of the element after firing in order to coat the winding and so to restrict volatilisation of the wire. It is preferable to refire the element and to give it a second thin coating of cement if necessary. This second coat is fired when the element is installed in its case.

All three designs of element give long lives under different working conditions. The D-shaped elements are used in closed-ended furnaces, such as that shown in Fig. 2, at temperatures up to 1650°C. The 5 cm bore tubular elements are used in open-ended horizontal furnaces mainly for heating substances having volatile constituents in a controlled atmosphere. Perforated alumina end plugs allow the inlet and outlet of gas.

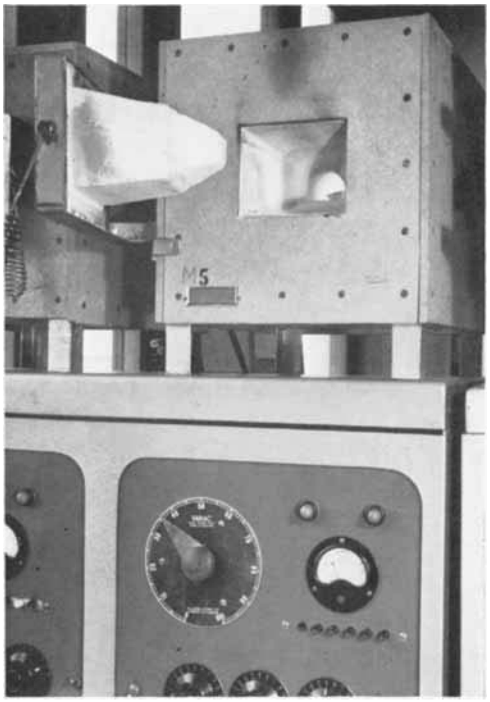

Fig. 2 A complete muffle furnace with its proportional controller

The 2.5 cm diameter elements are fitted into vertical quench furnaces used for the accurate determination of melting points and for the study of other phenomena by the well-known quenching method, and for the checking and calibration of thermocouples. These 2.5 cm elements are capable of attaining 1780°C with a very small temperature variation over the central 5 cm height of the furnace. The spacing of the turns specified below has been found to give optimum results. The winding starts 6 cm from the top end of the element; the turns per 2.5 cm are then respectively: 10, 8, 6, 4, 6, 8, 10, and the winding ends 2.5 cm from the bottom of the element. When the element is removed from the mould and before it is fired a few extra turns of wire are wound round the outside at each end to ensure that the ends are fired properly. These extra turns are removed before the element is inserted in its furnace.

If cracks develop in an element coating during use they should be covered with more cement slip, as maintenance of an even and impervious coat over the wire is the main factor needed to ensure a long life, but the grading of the refractory used ensures a low shrinkage and it is very rare for cracks to develop in the outer part of the element. The slip coating gives adequate electrical insulation to enable samples to be heated in platinum vessels placed on the floor of the muffle and these are invariably used. The temperature variation along the central 5 cm length of an element is less than 20°C, and with proportional controllers the temperature can be maintained to within 2°C for several hours.

The furnace cases are lined with high temperature insulating bricks and the element is surrounded by about 5 cm of alumina powder. The temperatures of the furnaces are controlled by various proportional controllers. An electromechanical type described by Nurse and Welch in 1950 (1) has been extensively used, and a more precise saturable reactor type gives the very close temperature stability (± 0.1°C) required for quench furnaces. The temperatures of the furnaces are measured by 5 per cent rhodium-platinum : 20 per cent rhodium-platinum thermocouples and read on an electronic recorder.

The work described formed a part of the programme of the Building Research Station and the paper is published by permission of the Director.

Reference

1 R. W. Nurse and J. H. Welch, *J. Sci. Instrum.*, 1950, **27**, (4), 97

Platinum-clad Isotope Fuel Capsule for Space Applications

As one of its long term objectives NASA continues to support work on radioactive heat sources and a recent report by Atomics International (USAEC Rept. NAA-SR-12578) provides some interesting preliminary design data for a proposed test capsule capable of holding a large (undisclosed) heat source and operating in a space environment for more than five years with a surface temperature of approximately 1090°C.

The total assembly, in the form of a cylinder with hemispherical ends is 7.37 inches long and 1.72 inches in diameter. The isotope heat source is centrally disposed, surrounded by a tantalum honeycomb and finally welded into a thick walled tantalum alloy shell which provides the strength for long term helium containment and for impact survival. An external covering of 10 per cent rhodium-platinum alloy, 0.020 inches thick, protects this shell from oxidation. Metallic diffusion between the tantalum and platinum alloys is inhibited by a thin layer of vapour phase deposited alumina. The outer surface of the platinum alloy is coated with a layer of iron titanate to increase heat emmissivity.

Paradoxically enough the design of this capsule was complicated because of its low operating temperature, no reliable creep data on rhodium-platinum alloys tested below 1200°C having yet been published. The designers extrapolated downwards with respect to temperature and outwards by a factor of 45 with respect to time. In concluding that hoop stresses in the rhodium-platinum sheath should be kept below 75 pounds per sq. inch they emphasise the uncertainties involved in their assumptions.

The compatibility studies scheduled in this report will be made in vacuum of 10^{-8} Torr for periods up to 2200 hours. In both geometry and environment these test conditions depart from those existing inside the proposed capsule. It will be interesting therefore to read in subsequent reports whether the reactions between tantalum, alumina and rhodium-platinum tested in close association inside the capsule in a helium atmosphere differ significantly from those which occur in vacuum where the reaction products are continuously removed.

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